Reclamation of the Londonderry Mine/Maxville Tailings site near Maxville, Montana

S.D. Bisch
Pioneer Technical Services, Inc., Butte, MT

B.E. Quiñones
Montana Dept. of Environmental Quality/Mine Waste Cleanup Bureau, Helena, MT

ABSTRACT: The Londonderry Mine/Maxville Tailings site is an abandoned hardrock mine located adjacent to Flint Creek in Granite County, Montana. Features associated with this site included two uncontained tailings ponds, two waste rock dumps, and a discharging adit . The largest waste rock dump at the site was situated on the steep, unstable west bank of Flint Creek and was contributing significant levels of metals into Flint Creek surface water and sediments. Flint Creek and several of its tributaries are critical habitat for Bull trout, a federally listed Category 2 species.

In 1995, the Montana DEQ entered into cooperative agreements with the USDI Bureau of Land Management, Granite County, and private landowners to reclaim the site. The reclamation project included installation of a temporary stream protection structure, excavation of the large waste rock dump from the creek bank, and consolidation of the material with the two tailings impoundments in a 1.5 acre capped repository on the east side of the creek. The remaining waste rock dump was stabilized (recontoured, amended, and revegetated) in place.

1 SITE DESCRIPTION

The Maxville site is an abandoned hardrock mine site listed on the Montana Department of Environmental Quality/Mine Waste Cleanup Bureau (MDEQ/MWCB) Priority Sites List. At this site, waste rock from the historic Londonderry Mine was eroding into Flint Creek, and the Londonderry Mine adit was discharging contaminated water over the waste rock and directly into the creek. Additionally, mill tailings from the site were affecting groundwater on the east side of Flint Creek. The contamination is from heavy metals, primarily arsenic, cadmium, lead, and zinc. The Maxville site is located adjacent to Flint Creek, along both the eastern and western banks, in the vicinity of Maxville, Montana (see Figure 1). The Londonderry Mine portion of the site (waste rock dumps and discharging adit) is located on patented and public land administered by the U.S. Department of Interior/Bureau of Land Management (BLM) on the western side of Flint Creek. The Maxville Tailings portion of the site is located on private and Granite County property on the eastern side of Flint Creek; this portion of the site contained two separate tailings impoundments, as well as municipal solid wastes intermixed with the mill tailings due to the tailings area historically being used as the old Maxville town dumpsite.

In 1995, the MDEQ/MWCB, BLM, and Granite County entered into a cooperative agreement to mitigate the environmental impacts resulting from this site.

1.1 *Location and Topography*

The legal description of the Londonderry Mine site is Township 8 North, Range 13 West, NE **3** of the SW **3** of the SW **3** of Section 4. The legal description of the Maxville Tailings site is Township 8 North, Range 13 West, NW **3** of the SW **3** of the SW **3** of Section 4.

The Londonderry Mine site is located adjacent to Flint Creek approximately 0.5 mile north of the town of Maxville. The Londonderry Adit is located within an isolated tract of BLM land which is bordered by private land to the east and north and by Deerlodge National Forest and private patented mining

claims to the west. The site elevation is approximately 4,800 feet above mean sea level. The terrain surrounding the site is generally rugged and consists of a relatively steep east facing slope that meets the relatively flat floodplain of Flint Creek. The creek flows near the western edge of its floodplain through this area and is directly adjacent to the Londonderry adit and mine wastes. Mining-related features associated with the Londonderry site included two waste rock dumps and associated collapsed adits (one discharging), several collapsing cabins and wooden structures, and various wooden, metal, brick, and concrete debris.

The Maxville Tailings site is located between Flint Creek and Boulder Creek approximately 0.5 mile northwest of the town of Maxville. The Maxville Tailings site is located on private and Granite County property; the county has used the site for a solid waste disposal dump in the past. When this dumpsite was operational, the disposed solid waste was routinely covered with tailings material; as a result, an unknown quantity of tailings was intermixed with the solid waste. The dumpsite and an additional, smaller tailings impoundment were located on relatively flat terrain on the east side of Flint Creek; these waste sources appear to be isolated from Flint Creek (via run-off and/or overland flow) due to the natural topography. A Montana Rail Link railroad track located immediately west of the tailings impoundments also served to isolate the tailings from the creek. The extreme northern portion of the dumpsite and the smaller, northern tailings impoundment were located on private property.

The two waste rock dumps associated with the site, as well as the discharging adit, were all located on the west side of Flint Creek, on relatively steep terrain. The toe of the largest waste rock dump (WR-1) was located directly in the floodplain and active stream channel of Flint Creek, this dump was extremely steep (oversteepened and/or undercut in areas) and was void of vegetation. This dump was actively eroding into the stream, and the adit associated with this dump, although collapsed, discharged water directly into Flint Creek after flowing over the surface of the dump. Access to this western portion of the site is limited to foot traffic only due to the lack of a bridge or vehicle crossing on Flint Creek.

1.2 *Vegetation/Wildlife*

No threatened or endangered species of plants are known to exist in the study area. Commercial timberlands are found in the study area. Knapweed (non-native) and other noxious weeds are found throughout the area. Control of noxious weeds in this area is difficult and costly due to close proximity with perennial streams, discouraging land managers from the use of effective herbicides. This portion of the Flint Creek floodplain contains both wetlands and dense riparian vegetation. No extensive riparian inventory has been completed along this portion of Flint Creek. The majority of riparian habitat is reported to be in "Proper Functioning Condition." Only those areas void or with sparse vegetation are in "Non-functioning" condition. In general, the area is fairly continuously forested and is important habitat for a variety of big game animals, fur bearers, waterfowl, and birds including: mule deer, elk, moose, black bear, beaver, bobcat, and various ducks/geese and mountain grouse.

Flint Creek is considered a Class 3 sport fishery which annually receives 192 recreational fishing days per mile. The total length of Flint Creek from its headwaters at Georgetown Lake to its confluence with the Clark Fork River at Drummond is 35.7 miles. The trout biomass in Flint Creek has been estimated at 74 pounds of trout per 1,000 linear feet of stream. Rainbow Trout and Brown Trout are abundant in Flint Creek, and West Slope Cutthroat Trout are present, but are uncommon due to limited proper habitat. Bull Trout are also present in this portion of Flint Creek. The Bull Trout is a federally listed Category 2 species. Some sources list the Bull Trout as common and abundant in Flint Creek, while others show it as uncommon or rare. Bull Trout spawning takes place in lower portions of Flint Creek and in larger tributaries from September to October during low water conditions. Any increase in fine materials in spawning areas could significantly reduce the emergence success of fry.

Flint Creek Water temperature is measured at zero to 16.5EC with the highest temperatures recorded during July and August. Water temperatures in September and October are marginal (7.5 to 14.0EC) for spawning Bull Trout. The amount of fine materials in the substrate, extreme stream flows, and high water temperatures above 8EC are common causes of mortality of Bull Trout eggs and alevins (BLM, 1995).

1.3 *Historic or Archaeologically Significant Features*

A Cultural Resource Inventory and Assessment was completed for the Maxville site in September 1995. The assessment concluded that the site has poor integrity due to natural deterioration, a modern exploration effort, and the use of the tailings area as the local dump. The site was not recommended to be eligible for the National Register of Historic Places.

1.4 *Land Use and Population*

Existing use of the tract of public land is as a visual corridor, fishery, livestock grazing, watershed, limited recreation, riparian enhancement and wildlife habitat. However, due to lack of legal and physical access, recreation is limited.

An estimated 60 residents live year-round in the town of Maxville, which is located 0.5 mile southeast (upstream) of the Maxville site. The nearest residence is located 1,300 feet east of the Londonderry adit, 200 feet east of the Maxville Tailings.

2 MINE WASTE SOURCES

2.1 *Waste Rock Dump #1*

Waste rock dump #1 (WR-1) was the largest dump located at the site and was situated along the steep, unstable west bank of Flint Creek. The toe of WR-1 extended into the active section of the creek for approximately 400 feet along the bank. The dump was extremely steep and was being actively undercut by the creek in areas. WR-1 was inaccessible by vehicles, being located on the west bank of the creek, all usable roads in the surrounding area were located on the east side of the creek, and no bridge crossings were present. The preliminary risk analysis conducted for the Maxville site using the Abandoned or Inactive Mine Scoring System (AIMSS) concluded that groundwater was the primary pathway of concern at the site (due to the relatively large volume of the tailings) and that WR-1 was a significant source of concern due to its risk of contributing to surface water degradation.

The volume of WR-1 was determined to be 6,200 cubic yards. Antimony, arsenic, barium, copper, iron, lead, mercury, silver, and zinc concentrations were significantly elevated in the dump. Waste samples from WR-1 passed the Toxicity Characteristic Leaching Procedure (TCLP) analyses , hence, the material did not demonstrate hazardous properties as described under the Resource Conservation and Recovery Act (RCRA).

2.2 *Waste Rock Dump #3*

Waste rock dump #3 (WR-3) was located in an intermittent drainage approximately 600 feet west of Flint Creek at an elevation of 4,950 feet above mean sea level (which places it approximately 190 feet higher in elevation than Flint Creek at its closest point). WR-3 was a relatively small dump; however, it was extremely steep, and the toe of the dump extended into the intermittent drainage and provided a direct route for eroded dump material to reach Flint Creek. The surface of WR-3 was devoid of vegetation, except for the top of the dump where a few grasses and Lodgepole pine trees were growing. The dump was very loosely compacted and relatively unstable on the downslope side. WR-3 was inaccessible by vehicles; being located on the west side of Flint Creek, all usable roads in the surrounding area were located on the east side of Flint Creek, and no bridge crossings were present. A rough, steep mining road approached WR-3 from a southeasterly direction (from the loadout structure located near the Londonderry adit); however, there was no access to this road.

The volume of WR-3 was determined to be 1,300 cubic yards. Concentrations of the following metals were significantly elevated in the dump: antimony, arsenic, barium, cadmium, copper, iron, lead, mercury, silver, and zinc. TCLP analyses determined that WR-1 did not demonstrate hazardous properties as described under RCRA.

Acid Base Accounting and agronomic data obtained for WR-3 indicated that WR-3 was a potential acid producer and approximately 12 tons of lime per acre would be required to successfully establish vegetation on this material (assuming 12-inch depth of incorporation). The pH of a composite sample

of WR-3 was 3.5; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth. Organic amendment of the dump material was advised due to the very low organic matter content (0.4%).

2.3 *Tailings Pond #1*

Tailings pond #1 (TP-1) was located on private property approximately 100-feet north of the large tailings impoundment at the site. TP-1 was situated in a flat semi-open area surrounded by heavy timber that was easily accessed by a 1/3-mile long dirt road which turns northwest off of Montana Highway 1 near Maxville.

The volume of TP-1 was determined to be 350 cubic yards. Concentrations of the following metals were significantly elevated in the tailings: antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc. TCLP analyses determined that TP-1 did not demonstrate hazardous properties as described under RCRA.

2.4 *Tailings Pond #2*

Tailings pond #2 (TP-2) was a large uncontained tailings impoundment located on the east side of Flint Creek. An unknown quantity of municipal solid wastes was intermixed with TP-2. In the past, Granite County used the site as a solid waste disposal dumpsite; however, the site was closed to dumping in the late 1980's. When the dumpsite was operational, the disposed solid waste was routinely covered and mixed with tailings.

TP-2 was situated in a flat open area surrounded by heavy timber that was easily accessed by a 1/3-mile long dirt road which turns northwest off of Montana Highway 1 near Maxville. The tailings appeared to be isolated from Flint Creek due to the natural topography (via run-off and/or overland flow). A Montana Rail Link railroad track located immediately west of the tailings impoundment also served to isolate the tailings from Flint Creek via a surface route.

The volume of TP-2 was determined to be 15,700 cubic yards. Concentrations of the following metals were significantly elevated in the tailings: antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc. TCLP analyses determined that TP-2 did not demonstrate hazardous properties as described under RCRA.

Multiple tailings samples were analyzed for cyanide. The measured cyanide concentrations were relatively low and ranged from 0.315 ppm to 1.17 ppm. For comparison purposes, four background soil samples were analyzed for cyanide. Concentrations of cyanide measured in the background soils ranged from <0.286 ppm (less than detection limit) to 0.897 ppm. The data indicated that the average concentration of cyanide in the tailings (0.689 ppm) was not significantly elevated above the average background concentration (0.546 ppm).

Multiple tailings samples were collected for organics analyses (volatile organic compounds [VOCs] and base-neutral, acid extractable compounds [BNAs, semi-volatile organics]). The organics samples were collected to investigate possible impacts resulting from past municipal solid waste dumping practices at the Maxville site. These samples were collected in a biased manner (i.e., collected in areas of stained soils or in areas where abundant solid wastes were found in test pits) to investigate possible organic contamination. No VOCs were detected in any of the samples. Several semi-volatile organics were detected in two of the samples at very low concentrations, including polyaromatic hydrocarbons (PAHs) and phthalates. The data indicated that no significant organic contamination existed at the site.

2.5 *Londonderry Adit*

The Londonderry Adit is associated with WR-1. The average discharge flow from the adit was determined to be approximately 15 gallons per minute, however the flow rate varied considerably according to seasonal and climatic changes. Water analyses for the discharging water included total metals, dissolved metals, field parameters (pH, SC, temperature, and alkalinity), and wet chemistry (chloride, sulfate, TDS, hardness). Additionally, samples were analyzed for arsenic (+3 and +5) and iron (+2 and +3) speciation.

The adit discharge exceeded federal Maximum Contaminant Levels (MCLs) for arsenic and antimony. Several Montana Human Health standards (HHS; MDEQ/WQB, 1995) were exceeded as well, including: arsenic; iron; manganese; and mercury.

3 SUMMARY OF THE RISK ASSESSMENT

The baseline human health risk assessment performed for the Maxville site followed the Federal Remedial Investigation/Feasibility Study (RI/FS) process for CERCLA (Superfund) sites. This abbreviated assessment involved two steps, hazard identification and risk characterization, which were accomplished by evaluating available data to select contaminants of concern (CoCs) and characterizing risk by comparing those concentrations to previously derived cleanup goals. Only nine metals are present at the site at concentrations significantly above background levels: arsenic, silver, cadmium, copper, iron, mercury, antimony, and zinc. The previously derived risk-based cleanup goals were for a recreational-use scenario and a residential-use exposure scenario.

Hazard quotient (HQ) values exceed one for the residential land use scenario for three CoCs (arsenic, lead, and antimony) via two exposure routes (soil and water ingestion); HQ values greater than one indicate the potential for harmful effects by a CoC through the specified pathway(s). The arsenic HQ value of 151.74 via the soil ingestion route comprises the majority of the total noncarcinogenic HQ. Hazard quotient values exceeded one for the recreational land use scenario for three CoCs via two exposure routes (arsenic-soil/dust ingestion; mercury and zinc-water/fish ingestion). The arsenic HQ value of 6.13 via the soil/dust route comprised the majority of the total noncarcinogenic HQ.

The human health risk assessment results for both the residential and recreational scenarios are similar, identifying arsenic in surface waste via soil ingestion as the primary exposure pathway. Reclamation alternatives focused on mitigating this exposure route.

An ecological risk assessment was performed for the Maxville site following Federal RI/FS guidance for CERCLA sites. This is intended as a screening-level ecological risk assessment, and the results are of a qualitative nature. Three groups of ecologic receptors were identified: aquatic life, terrestrial wildlife, and terrestrial plant communities.

Surface water concentration data were compared to acute aquatic life criteria and indicated little potential for aquatic life impacts via surface water. Stream sediment concentration data were compared to proposed sediment quality criteria and indicated the potential for aquatic life impacts due to apparent sediment toxicity for arsenic, lead, and zinc in Flint Creek below the Maxville site. Estimated deer ingestion doses were compared to literature-derived toxicological effect levels, and indicated a slight potential for impacts to deer due to uptake of lead. Source area surface concentrations were compared to the higher value of the range of plant phytotoxicity derived from the literature and indicated the potential for impacts to plant communities for arsenic, lead, and zinc.

The ecologic risk assessment indicated arsenic in surface wastes was the primary CoC, and the plant community was the primary receptor; lead in sediments was a secondary CoC and aquatic life a secondary receptor of concern. Reclamation alternatives addressed As in surface soils (as for human health) and mitigate sediment delivery to Flint Creek.

4 SUMMARY OF THE EXPANDED ENGINEERING EVALUATION/COST ANALYSIS

The following reclamation alternatives were developed and evaluated for the Londonderry Mine/Maxville Tailings site:

- Alternative 1: No Action
- Alternative 2: Institutional Controls
- Alternative 3: In-place Containment
- Alternative 4: Partial Removal And Containment
- Alternative 5: On-site Disposal in a Constructed Repository
- Alternative 6: Off-site Disposal in a Permitted Waste Disposal Facility

The alternatives were assessed based on the following seven NCP criteria:

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;

C reduction of toxicity, mobility, or volume through treatment;
C short-term effectiveness;
C implementability; and
C cost.

Based on a detailed analysis and comparative analysis of alternatives (comparison of risk reduction and cost), Alternative 5c: On-site Disposal in a Constructed Unlined Repository with a Lined Cap was selected as the preferred alternative by the MDEQ/MWCB. This alternative involved consolidating all of the on-site tailings (TP-1 and TP-2) in a 1.5 acre area on Granite County property where TP-2 was located, installing a temporary construction bridge and stream diversion structure in Flint Creek, permanently removing waste rock adjacent to Flint Creek (WR-1) and consolidating this material in the same 1.5 acre area, constructing a lined cap, grading out and treating the remaining waste rock dump at the site with lime and amendments, applying cover soil over the graded dump and repository cap, and establishing vegetation.

Shortly after the Expanded Engineering Evaluation/Cost Analysis (EEE/CA) was completed, MDEQ/MWCB authorized Pioneer to conduct an on-site, pilot-scale treatability test on the adit discharge to determine if water quality standards could be attained via utilizing a passive settling system (the least costly alternative evaluated for treating the adit discharge). Water quality modelling performed while the EEE/CA was being completed determined that a passive settling system could significantly reduce the concentrations of several of the contaminants of concern in the adit discharge but would not attain water quality standards for all contaminants. Results obtained from the treatability testing were in close agreement with the modelling results; concentrations of several metals were significantly reduced, however, water quality standards were not attained for all contaminants. Additionally, capital costs and operation and maintenance costs associated with operating a passive settling system at this site were estimated to be significant; approximately $75,000.00 in capital costs and $35,000.00 per year for annual operation and maintenance costs. This alternative was determined to be impractical for treating a perpetual average flow of 15 gallons per minute; consequently, no action was implemented for treating the adit discharge at this site. The site will be re-evaluated in the future if more practical technologies are developed and successfully implemented at other similar sites.

5 PROJECT CONSTRUCTION

A temporary, 50-foot bridge was necessary to allow access to the mine wastes on the west side of Flint Creek, and a stream protection structure was necessary to isolate Flint Creek from the waste rock excavation activities. The temporary bridge specified for the project consisted of a two piece, pre-fabricated bridge supplied by Hamilton Construction Company of Springfield Oregon. The stream protection structure used on the project consisted of a combination of silt fence, straw bales, and sand bags. The silt fence was installed along the toe of WR-1 using metal T-posts driven into the edge of the creek bed on 10-foot centers. The fabric was anchored along the bottom of the fence using a continuous row of sand bags, and two rows of straw bales were stacked along the inside of the silt fence fabric. The straw bales functioned as a deflector to shield the silt fence from any large pieces of waste rock that might become dislodged while excavating the material.

WR-1 was completely excavated and hauled to the consolidation area on the opposite (east) side of Flint Creek. WR-1 was excavated using a Hitachi 270LC track excavator, and the material was hauled using two 10 cubic yard capacity end dumps. The steep southern portion of the dump was excavated by constructing a 10 to 12-foot wide bench/road approximately half way up the steep slope. The waste rock material located above the bench was hauled out while advancing to the southern end of the dump, and the material located below the bench was hauled out while the excavator retreated back in a northern direction. To protect the stream protection structure and Flint Creek, waste rock located along the toe of the dump was hand shovelled into the excavator bucket and loaded onto the haul trucks.

While the excavator was retreating from the southern end of the dump, compost and straw mulch were alternately hauled in and applied to the excavated surface to provide nutrients and organic matter for later revegetation of the slope. The bench/road (approximately 6-feet finished width) was specified to remain in place to provide erosion control along the steep slope. After the excavation of WR-1 was completed, the slope was hydroseeded and covered with erosion control mat. Additionally, a row of straw bales was installed along the length of the bench to provide additional erosion protection along

the steep slope. Once the reclamation work at WR-1 was completed, the stream protection structure was removed.

WR-3 was located approximately one-quarter mile west of Flint Creek along a primitive road which originated near the center of WR-1. This road required some improvement work to make access to WR-3 for haul trucks and other equipment possible. WR-3 was extremely steep (1H:1V slope in areas) and was actively eroding into an intermittent drainage located adjacent to the dump. WR-3 was graded out to reduce the steep slopes and to match the surrounding topography. The dump was then amended with lime (12 tons/acre incorporated into the upper 12-inches of dump material) and was covered with a one-foot thick layer of coversoil (previously amended with compost). The soil was then hydroseeded and covered with erosion control mat. The access road to WR-3 was obliterated and revegetated after the reclamation activities were completed. After the reclamation work on the west side of Flint Creek was completed, the temporary bridge was removed.

Prior to reclamation, TP-2 encompassed a surface area of slightly more than 2 acres. The shallow outer portions of this tailings pond were excavated and consolidated within a 1.5 acre area in the center of the tailings. TP-1 and WR-1 were completely excavated and consolidated within this same area.

After all of the specified mine wastes were loaded and compacted in the consolidation area, a geosynthetic clay liner (GCL) was installed over the wastes. The GCL was overlain with a geocomposite drainage layer (geonet and thermally bonded filter fabric), and the final layer of the cap consisted of a 2-feet thick layer of compost-amended coversoil which was fertilized, seeded, and mulched. Cover soil for this project was obtained from a nearby privately owned source located approximately 3-miles north of the site. All of the seed mixes used on the project consisted of native grass and riparian vegetation species.

Ditches were constructed to divert run-on away from each of the reclaimed areas and the constructed cap. Temporary fences were constructed to surround each of the reclaimed areas to allow for the establishment of vegetation without interference from livestock or wildlife. Several of the roads at the site were obliterated and reclaimed; however, the main access road remained intact to allow access for monitoring the progress of the reclamation and maintenance, if necessary.

6 SUMMARY

Final seeding of the Londonderry Mine/Maxville Tailings Reclamation Project was postponed from the late fall 1996 to the spring of 1997 due to heavy snow and frozen soil conditions. The project was completed within the engineer's cost estimate. All project objectives were accomplished, and the project took 42 work days to complete.

The construction cost for the project was $397,236.72. The total engineering cost for the project was $144,855.69. The Work Plan, Field Sampling Plan, and other supporting documents for the project cost $17,444.27. The reclamation investigation and risk assessment cost $39,548.26 including all analytical costs. The cost for preparation of the Expanded Engineering Evaluation/Cost Analysis was $16,393.18. Pilot-scale treatability testing of the adit discharge cost $14,703.00, including construction, analytical, and reporting. Engineering design and bid specification preparation cost $20,524.12. The total project cost was $542,092.41.

8 REFERENCES

Bureau of Land Management, 1995. U.S. Department of the Interior, Garnet Resource Area, Londonderry Mine Reclamation Project, Removal Site Evaluation, May 10, 1995.

Bureau of Land Management, 1990. U.S. Department of the Interior, Final Screening Site Inspection Report, Londonderry Mine Adit Site, Butte District, Montana, July 27, 1990.

EPA, 1989b. Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (Interim Final). U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/001.

EPA, 1989c. Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory

Reference. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR. EPA/600/3-89/013.

Montana Department of Fish, Wildlife and Parks, 1989. Montana Rivers Information System Report, Version 2.0, December 1989.

Montana Department of Environmental Quality/Abandoned Mine Reclamation Bureau, 1996a. Expanded Engineering Evaluation/Cost Analysis for the Maxville Tailings/Londonderry Mine, Prepared by Pioneer Technical Services, Inc., May 1996.

Montana Department of Environmental Quality/Abandoned Mine Reclamation Bureau, 1993. Hazardous Materials Inventory Site Investigation Log Sheet for Maxville Site, Prepared by Pioneer Technical Services, Inc., September 9, 1993.

Montana Department of Environmental Quality/Water Quality Bureau. Circular WQB-7, Montana Numeric Water Quality Standards, July 15, 1995.

U.S. Geological Survey, 1996. Daily Mean Flow Rate Data for Flint Creek at Maxville, Montana.

U.S. Geological Survey, 1993a. Water Resources Division, Water Monitoring for Flint Creek, Helena, Montana, February 17, unpublished.

U.S. Geological Survey, 1993b. "Preliminary Summary of Metal Characteristics in Flint Creek and Londonderry Mine Discharge at Maxville, Montana", water year 1991, unpublished.

U.S. Geological Survey, 1987. Results of Water Sampling of Londonderry Mine Adit and Flint Creek, Granite County, Montana, unpublished.

U.S. Geological Survey, 1971. Topographic Map of Maxville, Montana, 7 1/2 minute Quadrangle, 1971.